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VOLTAGE QUALITY CONTROL IN WIND TURBINE AND FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) DEVICES IN POWER SYSTEMS BY USING STATIC VAR COMPENSATION (SVC)

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Abstract : In recent years, wind turbines have become an acceptable alternative for electrical energy generation, because of the environmental and economic benefits of it. Much research remains to improve wind turbines behavior and make them more reliable and profitable. The reason for study application of wind turbine power quality characteristics determine the impact of wind turbines on voltage quality. This paper gives a brief description of the impact that wind turbines may have on the voltage quality which explained through a case study of (16 x 750 kW) wind farm on a (30 kV) distribution feeder.The case that have been studied shows that possible voltage quality problems can managed to overcome them by selecting an appropriate wind turbine type and by adjusting wind turbine control parameters.The reactive power demand for the generator of wind turbines is compensated using uncontrollable capacitor banks and control Static Var Compensation (SVC) in flexible ac transmission system (FACTS) devices. This paper utilized the MATLAB/SIMULINK software in the modeling of such a wind squirrel-cage induction generator with grid in power system in two cases, fixed speed with directly grid connected squirrel-cage induction generator and variable speed with squirrel-cage induction generator. This model allows for the addition of wind energy generators to grid with wind turbine of (12 MW).The results obtained from our model in the case of constant wind speed using SVC showed the improvement in the value of Bas-Bar$_2$ ($V_{abc.B.B2}$) from (0.9 p.u) to (1 p.u) and reducing the reactive power value of Bas-Bar$_2$ ($Q_{.B.B2}$) from (8 Mvar) to (2 Mvar). The results of controlled system used in our model in the case of variable wind speed with (fixed Var control, voltage regulation) showed that damping oscillating of voltage in the case of voltage regulation is best from the fixed Var control .

Key words: *Wind Turbine, Static Var Compensation (SVC), Wind Speed Modeling, Flexible ac Transmission System (FACTS).*

السيطرة على كمية الفولتيةِ في توربينِ الرياح ونظامِ أدوات الإرسالِ المرنِ المتناوب في أنظمة القدرة الكهربائية باستخدام المعوض الساكن (SVC)

الخلاصة:في السنوات الاخيرة اصبحت توربينات الرياح بديلا مقبولا لتوليد الطاقة الكهربائية بسبب المنافع البيئية والاقتصادية لها. يبقى الكثير من البحث لتحسين سلوك توربينات الرياح ويجعلها اكثر موثوقيتا وربحا. السبب من دراسة تطبيق توربينات الرياح لتقدير تاثير توربينات الرياح على نوعية وكمية الفولتية.هذا البحث يعطي وصف تاثير توربينات الرياح على نوعية وكمية

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الفولتية موضحة من خلال دراسة محطة طاقة هوائية تتكون من (١٦) وحدة كل منها (750 kw) في خط نقل (٣٠ kv). تبين الحالة التي تم دراستها بان مشاكل كمية الفوليتة المحتملة يمكن التغلب عليها من خلال اختيار نوع توربين الرياح الملائم وبتعديل عناصر السيطرة المستخدمة في توربين الرياح. ان القدرة الكهربائية المفاعلية المطلوبة لمولد توربينات الرياح تتولد باستخدام بنوك المكثف غير المسيطر و معوض SVC المسيطر في خطوط انظمة النقل المتناوبة المرنة. تم استخدام نمذجة ماتلاب في عرض الموديل المستخدم فيه مولد رياح حثي نوع قفص سنجابي مع الشبكة في نظام القدرة في حالتين ذات السرعة الثابتة والسرعة المتغيرة. هذا الموديل يسمع لإضافة مولدات طاقة الرياح الى الشبكة مع توربين رياح ذو قدرة (12 Mw). النتائج التي استحصلت من الموديل الخاص بالبحث في حالة ثبات سرعة الريح باستخدام المعوضات الساكنة اظهرت تحسن قيمة فولتية الباس – بار ٢ من (0.9 p.u) الى (1 p.u) وتقليل قيمة القدرة المفاعلية من (8 Mvar) الى (2 Mvar) . نتائج نظام السيطرة المستخدم في حالة السرعة المتغيرة (مع سيطرة ثابتة و تنظيم الفولتية) اظهرت اخماد تذبذب الفولتية يكون افضل في حالة السيطرة على تنظيم الفولتية مما في السيطرة الثابتة.

1. Introduction

The main function of an electrical power system is to transport electrical power from the generators to the loads. In order to function properly, it is essential that the voltage is kept close to the nominal value, in the entire power system. This is achieved differently for transmission networks and distribution grids. [1]

The voltage level in the transmission system is kept at a technical and economical optimum by adjusting the reactive power supplied or consumed. Power plants and special equipment, (capacitors and reactors) control the reactive power. The voltage ratio of different voltage levels can be adjusted by tap-changers in power transformers. This requires a reactive power flow between different voltage levels.

In order to manage the voltage level during disturbances, reactive reserves in power plants are allocated to the system. These reserves are used mainly as primary reserves in order to guarantee that the voltage level of the power system remains stable during disturbances. Voltage level management has the aim to prevent under voltages and over voltages in the power system and to minimize grid losses. Voltage level management also guarantees that customer connection points have the voltages that were agreed by contracts. [2]

A similar problem arises when large-scale wind farms are connected to the transmission system. The wind farm affects the power flows and hence the node voltages, transmission system therefore voltages are controlled mainly by large scale conventional power plants. If their capability to control voltages within the transmission network is not sufficient to compensate the impact of the wind farm on the node voltages, again, the voltage at some nodes can no longer be kept within the allowable deviation from its nominal value and appropriate measures have to be taken. [3]

This paper looks at the impact of wind power on voltage control will review the essential and basic principles of voltage control and comment on the impact of wind power on voltage control.

This paper introduced a constant-speed wind turbine (type A) that are used in model and analysis your voltage control capabilities and using steady-state. Dynamic simulation results for this paper presented measure and evaluate the power quality impact of constant-speed wind turbine on the grid of the system.

2. Volt amperes Reactive (VARs)

VARs are reactive or imaginary power and do no useful work but are essential to properly magnetize and control induction machines, transformers and other inductive devices. VARs, effectively controlled, can cause induction machines to behave much like self excited synchronous machines. Effective VAR supply can control grid voltage, stabilize the grid and improve grid quality. [1]

3. Flexible Alternating- Current Transmission System (FACTS) DEVICES

(FACTS) is emerging as a potentially very powerful tool that can materially improve the performance of transmission and distribution systems. Static VAR compensators are at the low end of FACTS technology and have been evolving for nearly 30 years, but only recently have they become widely used. The simplest static var compensats (SVC) uses transient free thyristor switching of capacitors to provide automatic VAR support. Such devices can be turned on, off and back on every other cycle and can provide responsive VAR support, including voltage control, to improve grid stability. SVC technology which is effectively when it supplies to the system can also be used effectively with Type A wind turbine to provide much the same capability, but with VAR support dropping off with voltage more rapidly. As SVC devices may be lower in cost it is more feasible to purchase devices of sufficient size to accommodate voltage drops of as much as 50 %. [4, 5]

4. Reactive Compensation and Voltage Control

The effect of applying reactive power compensation to manage the voltage-rise effect and hence allow an increase in penetration of wind generation. This achieved by absorbing reactive power at the point of connection. In this case, active power generation would be curtailed only when the reactive power absorbed is insufficient for maintaining the voltage within permissible limits. The capacity of reactive power compensating plants may therefore be important in limiting generation curtailment. The effectiveness of reactive compensation will be system-specific. In order to simulate this, a static VAR compensator (SVC), with various capacities, has been added to the point of connection. Figure (1) shows the amount of energy generated for various penetration levels and various reactive compensation capacities. [6]

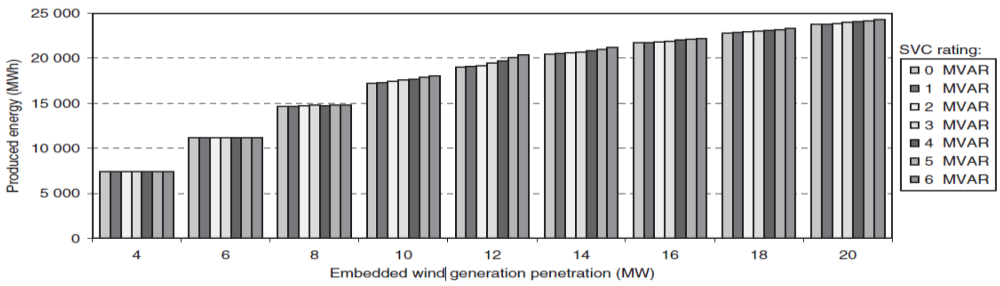

Figure (1): Energy generated by the wind farm, by static VAR compensator (SVC) rating

5. Power Quality Problems

A wind turbine is designed to supply active power to the grid. A reactive power exchange between the wind turbine and the grid depends on the type of the wind turbine; it can be consumed, produced or no reactive power can be exchanged with the grid. As a consequence of this fact, the voltage at the point of common connection, U_{PCC}, is influenced. This is demonstrated in figures (2) and (3) and it described in Equation (1). [6, 7]

$$U_{PCC} = R_g \frac{p}{U_N} + X_g \frac{q}{U_N} + U_N \quad (1)$$

Where:

U_{PCC}: voltage at the point of common connection (PCC),

R_g: grid resistance,

U_N : nominal voltage of the grid,

X_g: grid reactance,

P; p: active power produced,

Q; q: reactive power consumed,

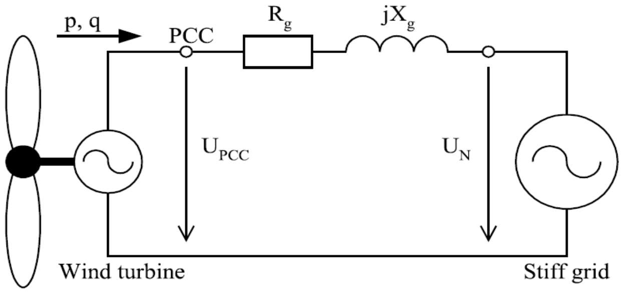

Figure (2): Connection of a wind turbine to the grid

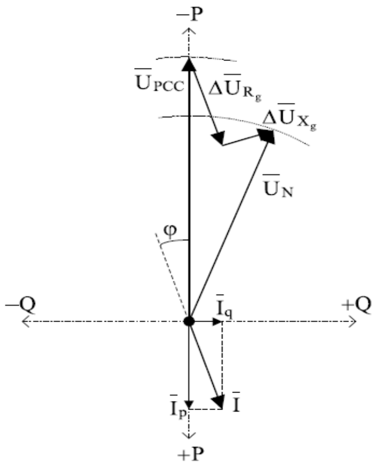

Figure (3): Vector diagram

ΔU_{R_g} : voltage drop over the grid resistance,

ΔU_{X_g} : voltage drop over the grid reactance,
I: generator current,
Ip: generator current, at active power corresponding component,
Iq: generator current, at reactive power corresponding component,
φ: angle between voltage and current vectors.
Higher active power production, i.e. a higher Ip, is followed by an increase in the voltage drop over the grid resistance, ΔU_{R_g} , and a consequent increase in the voltage U_{PCC}. More consumed reactive power, i.e. higher Iq, causes, on the contrary, an increase in the voltage drop over the grid reactance and a corresponding decrease in the voltage U_{PCC}.

A power quality evaluation of a wind turbine is addressed for two different operational modes. First, it is investigated under normal operation during which aspects, such as the steady state voltage impact, dynamic voltage variations and the harmonic distortion on the grid are of interest. Second, the impact on the grid when a turbine is being connected, i.e. during the start up of the turbine, is analyzed. Voltage dips and their consequences are of interest here. Voltage transients originating in the switching of a capacitor bank are another power quality problem of interest when analyzing the start up of a turbine. [8, 9]

6. Steady State Voltage Impact

The steady state voltage level at the PCC is a power quality problem which is common to most of the wind turbine systems. It is, by its nature, the problem potentially related to any source or load of electric power. Since the distribution (transmission) lines will always have an impedance, there must be a voltage drop (increase) in it in order to make it possible for power to be transmitted. Since the voltage in the system must be kept within stated limits, the voltage drop in the grid impedance must not exceed the stated value.
In the case of a conventional power station, the natural way of avoiding such a problem is to design the transmission lines according to specific requirements. This is, however, rarely the case with a small wind turbine installation. Building new transmission lines or reinforcing present ones in such a case is almost never done, it would be far too expensive compared with the total gain from the installation.

An installation of large wind parks, today typically located offshore, with a number of turbines is, of course, a completely different situation. In such a case, adjusting transmission capacity is not a major cost in the overall scope of such a project.
Keeping the voltage at PCC below given limits without any need for grid reinforcement is, as discussed above, a typical problem in the installation of one or few wind turbines. [9]

7. Model of Wind Turbine Constant-Speed

Figure (4) depicts the general structure model of a constant-speed wind turbine. This general structure consists the models of the most important subsystems of wind turbine type, namely, the rotor, the drive train and the generator combined with a wind speed model. [8, 10]

The generator is directly connected to the line, and may have automatically switched shunt capacitors for reactive power compensation and possibly a soft-start mechanism which is bypassed after the machine has been energized. The speed range of the turbine is fixed by the torque vs. speed characteristics of the induction generator. A layout showing a general configuration of a constant-speed wind turbine is shown in Figure (5). [10]

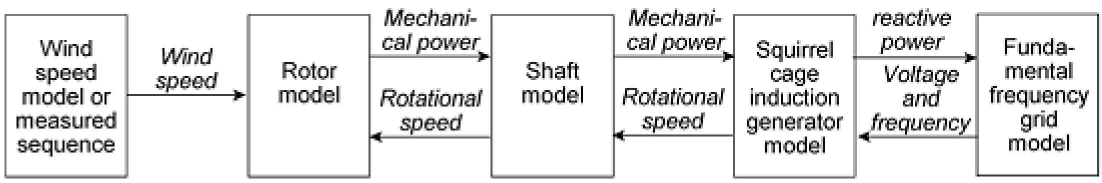

Figure (4): General structure model of constant-speed wind turbine

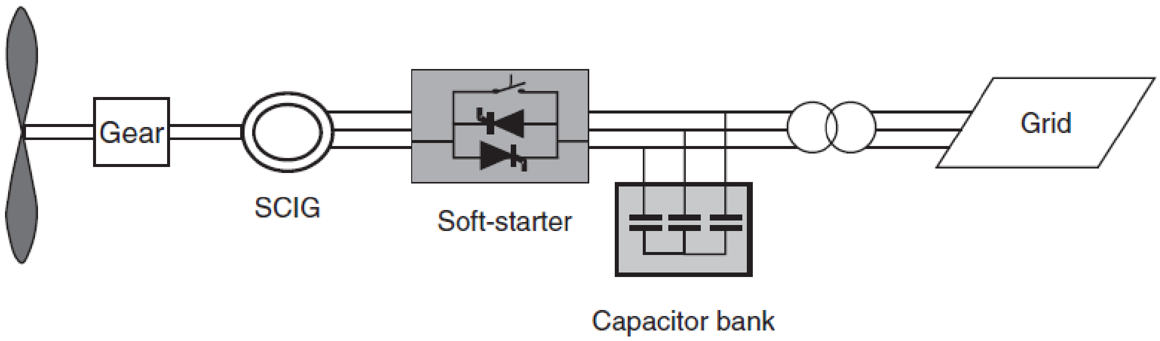

Figure (5): Constant-speed wind turbine

7.1. Model A Wind Speed

As in first block of figure (5). One approach to model a wind speed sequence is to use measurements. The advantage of that a 'real' wind speed is used to simulate the performance of the wind turbine. The disadvantage is, however, that only wind speed sequences that have already been measured can be simulated. If a wind speed sequence with a certain wind speed range or turbulence intensity is to be simulated, but no measurements that meet the required characteristics are available, it is not possible to carry out the simulation. A more flexible approach is to use a wind speed model that can generate wind speed sequences with characteristics to be chosen by the user. This makes it possible to simulate a wind speed sequence with the desired characteristics, by setting the value of the corresponding parameters to an appropriate value. In this paper

concerning the simulation of wind power in electrical power systems, it is often assumed that the wind speed is made up by the sum of the following four components:
a- The average value.
b- Ramp component, representing a steady increase in wind speed.
c- Gust component, representing.
d- Component representing turbulence.
This leads to the following equation:

$$Vw(t) = Vwa + Vwr(t) + Vwg(t) + Vwt(t) \quad (2)$$

in which $Vw(t)$ is the wind speed at time t.
Vwa is the average value of the wind speed.
$Vwr(t)$ is the ramp component.
$Vwg(t)$ is the gust component.
and $Vwt(t)$ is the turbulence component.
The wind speed components are all in 'metres per second', and time t is in seconds. In this paper we represent equation (2) by using matlab simulating as in figure (6) which shows an example of a wind speed sequence generated using simulating of matlab.

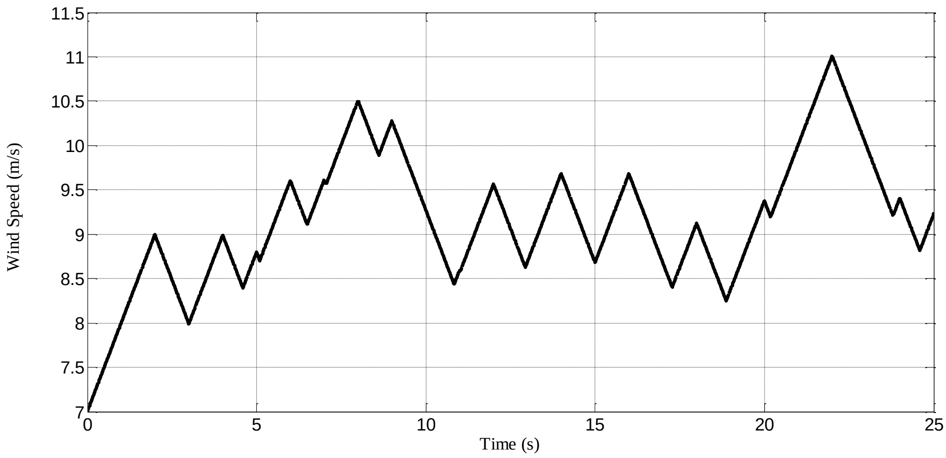

Figure (6): Simulated wind speed model

7.2. Rotor Model

The following well-known algebraic equation gives the relation between wind speed and mechanical power extracted from the wind:

$$Pwt = \frac{p}{2} AwtCp(\lambda, \theta)V^3w \quad (3)$$

where (Pwt) is the power extracted from the wind in watts.
(p) is the air density (kg/m3).
(Awt) is the area covered by the wind turbine rotor (m^2).

(Cp) is the performance coefficient or power coefficient.

(λ) is the tip speed ratio($\frac{Vt}{Vw}$), the ratio between blade tip speed, (Vt) (m/s), and wind speed at hub height upstream of the rotor, (Vw)(m/s).

(θ)is the pitch angle (in degrees).

Most constant-speed wind turbines are stall controlled. In that case, (θ) is left out and (Cp) is a function of (λ) only. [10]

In this paper a matlab simulation used to represent equation (3) as a block diagram which shown in figure (7). The simulated model of this block diagram shows how the factors of equation (3) can affect at the generated power from wind turbine.

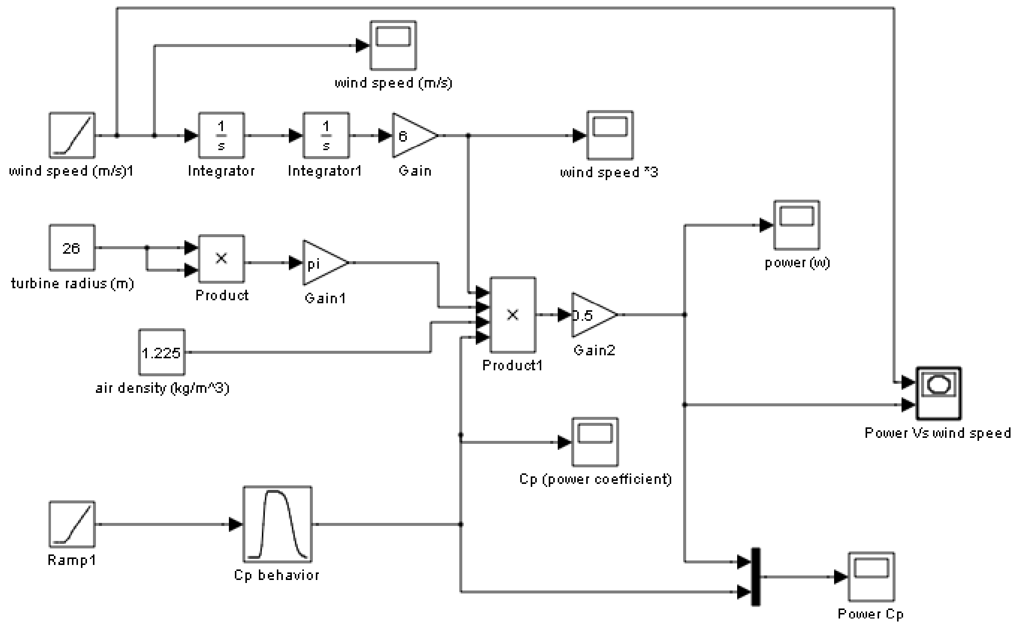

Figure (7): Power wind turbine in Matlab/ Simulink model

7.3. Shaft Model

It has been repeatedly argued in the literature that the incorporation of a shaft representation in models of constant-speed wind turbines (Type A) is very important for a correct representation of their behavior during and after voltage drops and short circuits. This is because of the fact that the low-speed shaft of wind turbines is relatively soft. The models presented here are to be used for power system dynamics simulation PSDS, these are among others, used for analyzing a power system's response to the mentioned disturbances. It is therefore essential to incorporate a shaft representation into the constant-speed wind turbine model. However, only the low-speed shaft is included. The gearbox and the high speed shaft are assumed to be infinitely stiff. The resonance frequencies associated with gearboxes and high-speed shafts usually lie outside the frequency bandwidth that we deal with in PSDSs. [3]

Therefore, we use a two-mass representation of the drive train. The two-mass representation is described by the following equations:

$$\left.\begin{aligned}\frac{d\omega_{wr}}{dt} &= \frac{T_{wr} - K_s\gamma}{2H_{wr}},\\ \frac{d\omega_m}{dt} &= \frac{K_s\gamma - T_e}{2H_m},\\ \frac{d\gamma}{dt} &= 2\pi f(\omega_{wr} - \omega_m),\end{aligned}\right\} \tag{4}$$

(t) is the time in which (f) is the nominal grid frequency; (T) is the torque; (γ) is the angular displacement between the two ends of the shaft; (ω) is frequency; (H) is the inertia constant; and (K_s) is the shaft stiffness. The subscripts (wr, m and e) stand of wind turbine rotor, generator mechanical and generator electrical, respectively. All values are in per unit, apart from (K_s), (γ) and (f), which are in p.u./el. rad., degrees, and Hz, respectively. [9]
The shaft is depicted schematically in Figure (8), which includes some of the quantities from equation (4).

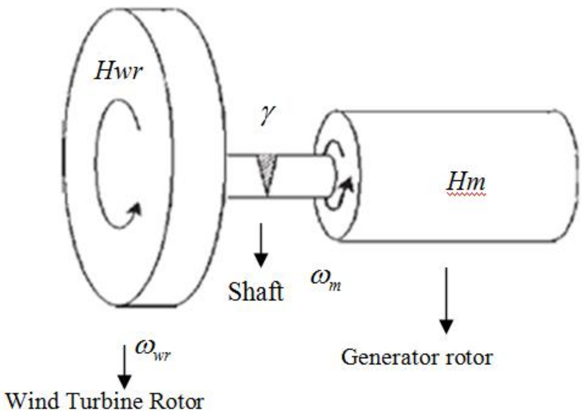

Figure (8): Schematic representation of the shaft

7.4. Generat Model GENERATOR MODEL

The voltage equations of a squirrel cage induction generator in the d – q (direct quadrative) reference frame, using the generator convention, can be written as in equation (5):

$$\left.\begin{aligned}u_{ds} &= -R_s i_{ds} - \omega_s\psi_{qs} + \frac{d\psi_{ds}}{dt},\\ u_{qs} &= -R_s i_{qs} + \omega_s\psi_{ds} + \frac{d\psi_{qs}}{dt},\\ u_{dr} &= 0 = -R_r i_{dr} - s\omega_s\psi_{qr} + \frac{d\psi_{dr}}{dt},\\ u_{qr} &= 0 = -R_r i_{qr} + s\omega_s\psi_{dr} + \frac{d\psi_{qr}}{dt},\end{aligned}\right\} \tag{5}$$

in which (s) is the slip, (u) is the voltage (i) is the current, (R) is the resistance, and (ψ) is the flux. All quantities are in per unit. The subscripts (d) and (q) stand for direct and quadrature component, respectively, and the subscripts (r) and (s) for rotor and stator, respectively. The generator convention is used in this equation, which means that a current leaving the machine is positive, whereas a current entering the machine is negative. The opposite of the generator convention is the motor convention, where a current entering the machine is positive whereas a current leaving the machine is negative. The equations for active power generated, (P), and the reactive power consumed, (Q), are: [9]

$$\left.\begin{aligned} P_s &= u_{ds}i_{ds} + u_{qs}i_{qs}, \\ Q_s &= u_{qs}i_{ds} - u_{ds}i_{qs}. \end{aligned}\right\} \quad (6)$$

Because only the stator winding is connected to the grid, generator and grid can exchange active and reactive power only through the stator terminals. Therefore, the rotor does not need to be taken into account. The values of the various parameters are dependent on the generator rating and can be derived from tables and graphs. Table (1) includes the practical parameters of generator used in this paper.

Table (1): Simulated induction generator parameters

Generator characteristic	Value
Number of poles, p	4
Generator speed (constant-speed; rpm)	1517
nominal grid frequency, f	50
Mutual inductance, Lm (p.u.)	3.0
Stator leakage inductance, L_s (p.u.)	0.10
Rotor leakage inductance, L_r (p.u.)	0.08
Stator resistance, R_s (p.u.)	0.01
Rotor resistance, R_r (p.u.)	0.01
Compensating capacitor (constant-speed; p.u.)	0.5
Moment of inertia H_m (s)	0.5

8. The Power system Model Research

This paper is describes and illustrates the modeling of wind turbine using squirrel cage induction generator (SCIG) with shunt capacitors uncontrolled and controlled (SVC) in cased variable wind speed are connected to the induction generator to provide the self-excitation. The amount of capacitance connected determines the voltage level based on the operating point on the induction generator's saturation curve using FACT devices compensation control to study effect changing wind on steady-state and dynamic performance to voltage control in wind power plant 12 MW and grid.

The single-line diagram shown in figure (9) represents a wind power plant (16 x 750 kW=12 MW), (50 Hz), (700 V) the wind farm connected to a 30 kV distribution system exporting power to a132 kV grid through a 30 km 30kV feeder. The transmission line is (30 km) connected between buses B.B1, B.B2.

The power system modeling consists on wind speed model with changing wind during different times in wind turbine squirrel cage induction generator (SCIG) with need for installing capacitor banks to absorb reactive power to reduced voltage fluctuations in power system.

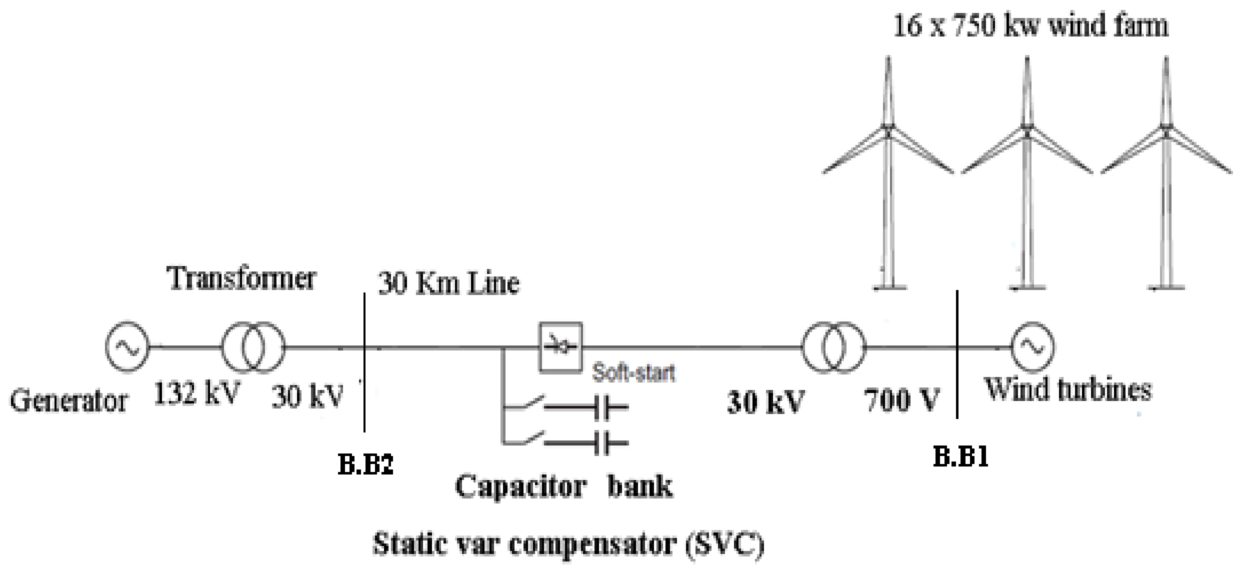

Figure (9): Single-line diagram wind power system station (12) MW

9. Conventional Static VAR Compensation (SVC)

The SVC behaves like a shunt-connected variable reactance, which either generates or absorbs reactive power in order to regulate the voltage magnitude at the point of connection to the AC network .In its simplest form, the SVC consists of a thyristor-controlled reactor (TCR) in parallel with a bank of capacitors. The thyristors firing angle control enables the SVC to have an almost instantaneous. Speed of response. It is used extensively to provide fast reactive power and voltage regulation support. It is also known to increase system stability margin and to damp power system oscillations. [11]

In power flow studies the SVC is normally modeled as a synchronous generator with zero active power generation; upper and lower limits are given for reactive power generation. The generator representation of the SVC is changed to a constant admittance if the SVC reaches one of its limits.

A more flexible and realistic SVC power flow model is presented below. It is based on the concept of a non-linear shunt reactance, which is adjusted using Newton's algorithm to satisfy a specified voltage magnitude at the terminal of the SVC The schematic representation of the SVC and its equivalent circuit are shown in figure (10), where a TCR is connected in parallel with a fixed bank of capacitors. [12, 13]

An ideal variable shunt compensator is assumed to not contain resistive components, GSVC = 0. Accordingly, it draws no active power P_1 from the network. On the other hand, its reactive power Q_1 is a function of nodal voltage magnitude at the connection point, say node ι, and the SVC equivalent susceptance B_{SVC}:

$P_1=0$

$$Q_1= - |V_1|^2 B_{SVC} \quad (7)$$

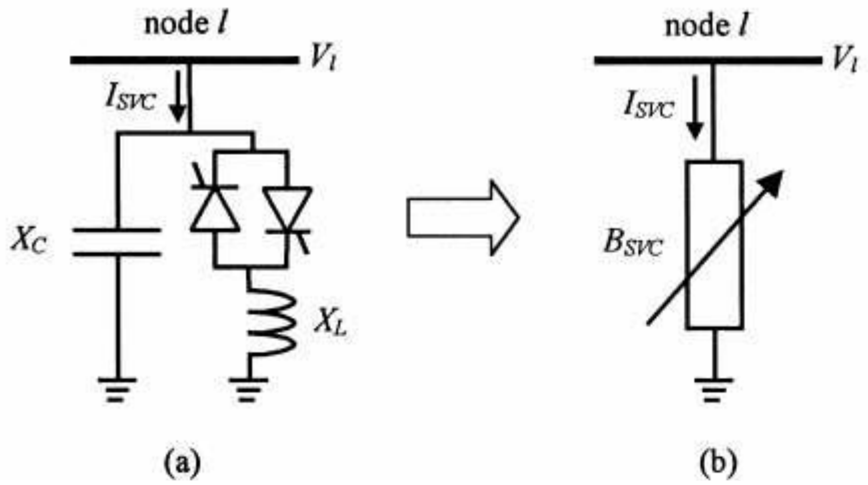

Figure (10): Static Var Compensator (SVC). (a) structure formed by fixed capacitor and thyristor-controlled reactor (TCR), (b) variable suscceptance representation

10. The Static VAR Compensator (SVC) Concepts

10.1. Static Var Compensator (SVC) Description

The static var compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids.

The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). [14]

When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR). [15, 16]

10.2. Single-line diagram of SVC and its control system

Figure (11) shows a single-line diagram of a static var compensator and a simplified block diagram of its control system which consists of:

i) A measurement system that measure the controlled positive-sequence voltage. A fourier- based measurement system using the average of one-cycle running. [17]

ii) A voltage regulator that used the voltage error (difference between the measured voltage (Vm) and the reference voltage (Vref)) to determine the (SVC) susceptance (B) needed to keep the system voltage constant.

iii) A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of (TCRs).

iv) A synchronizing system using a Phase-Locked Loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors. [18]

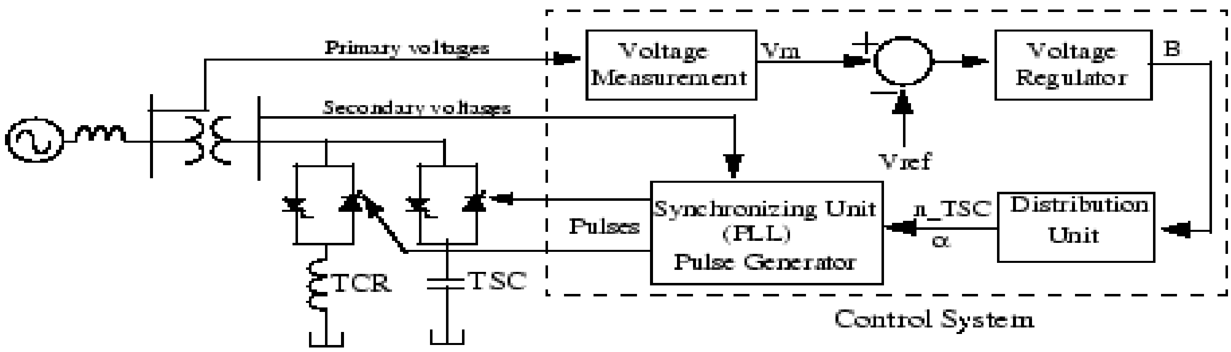

Figure (11): The single-line diagram of SVC control system

11. Simulation of Facts Devices Compensation Used In This Paper

The model used in this paper has wind power plant with 16- squirrel cage induction generator (SCIG) type 750 kW. Wind speed model and capacitor banks uncontrolled and controlled used to regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the wind turbine and also using the control static var compensator (SVC) (shunt device of the flexible ac transmission systems (FACTS)).The compensation used power electronics to control power and improve transient stability on power grids with voltage regulation connected in transmission line during models as shown simulation form of figure (12).

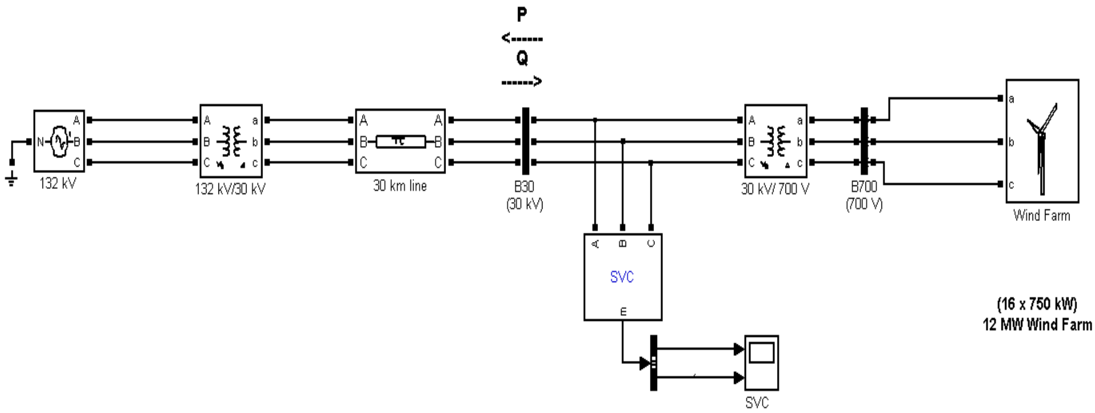

Figure (12): Simulated model of wind power

12. Simulation Results and Discussions

As refers in section (9), the model which consists of (SVC) and (FACTS) system is simulated by matlab software. The case study further showing that possible voltage quality problems resulting from a wind turbine installation in more from cases which of exigency using by selecting an appropriate modeling to wind turbine type (A) and also by adjusting according wind turbine control with parameters improve working wind farm in grid according effecting in changing wind speed.

The turbine response to effect a change in wind speed variation studied in proposed model of this paper.

The results presents an attempt to design a simulations model with static var compensator (SVC) is a shunt device of the flexible ac transmission systems (FACTS) family compensation in transmission lines of power system which consist the analysis of the capacitor phenomena in both static and dynamic states:

A- Static Analysis

i. Constant Wind Speed Without Static VAR Compensator (SVC)

In order to compute the voltage quality limit. Line capacities, generator capabilities and voltage-dependent on characteristics wind speed considered, so an estimation of the voltage stability limit is obtained, when the operation point in the proximity of the voltage collapse point which yield to divergence of the power flow to its grid.

Figure (13) shows the presented results of model wind power plant without (SVC) with average wind speed (8-11) m^2/s and period time (0-1) s.

ii. Constant Wind Speed With Static VAR Compensator (SVC)

In order to improve the voltage stability conditions that a FACTS can produce in the system with a wind farm connected to a grid, power system simulation is also performed in MATLAB/SIMULINK as shown in figure (12) a 12 MW wind farm consisting of single Squirrel Cage Induction Generator (SCIG) driven is connected to a power grid 30 kV distribution system through a 30 km with static var compensator (SVC) with average wind speed (8-11) m^2/s and period time (0-1) s. (SVC) connect (FACTS) at $B.B_2$ bus to provide reactive compensation as shown in figure (14).

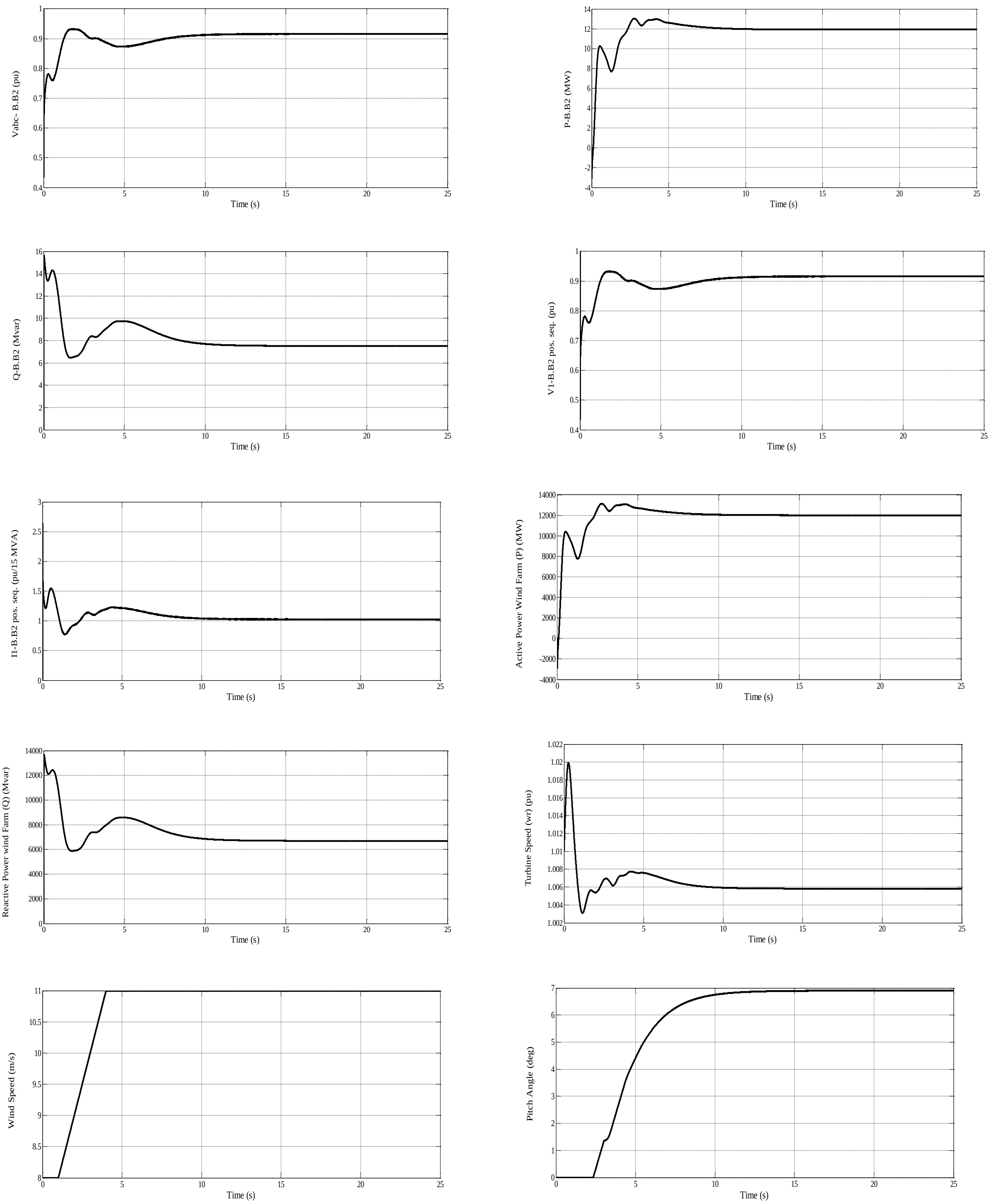

Figure (13): Results of wind power plant model without (SVC) with average wind speed (8-11) m^2/s and period time (0-1) s

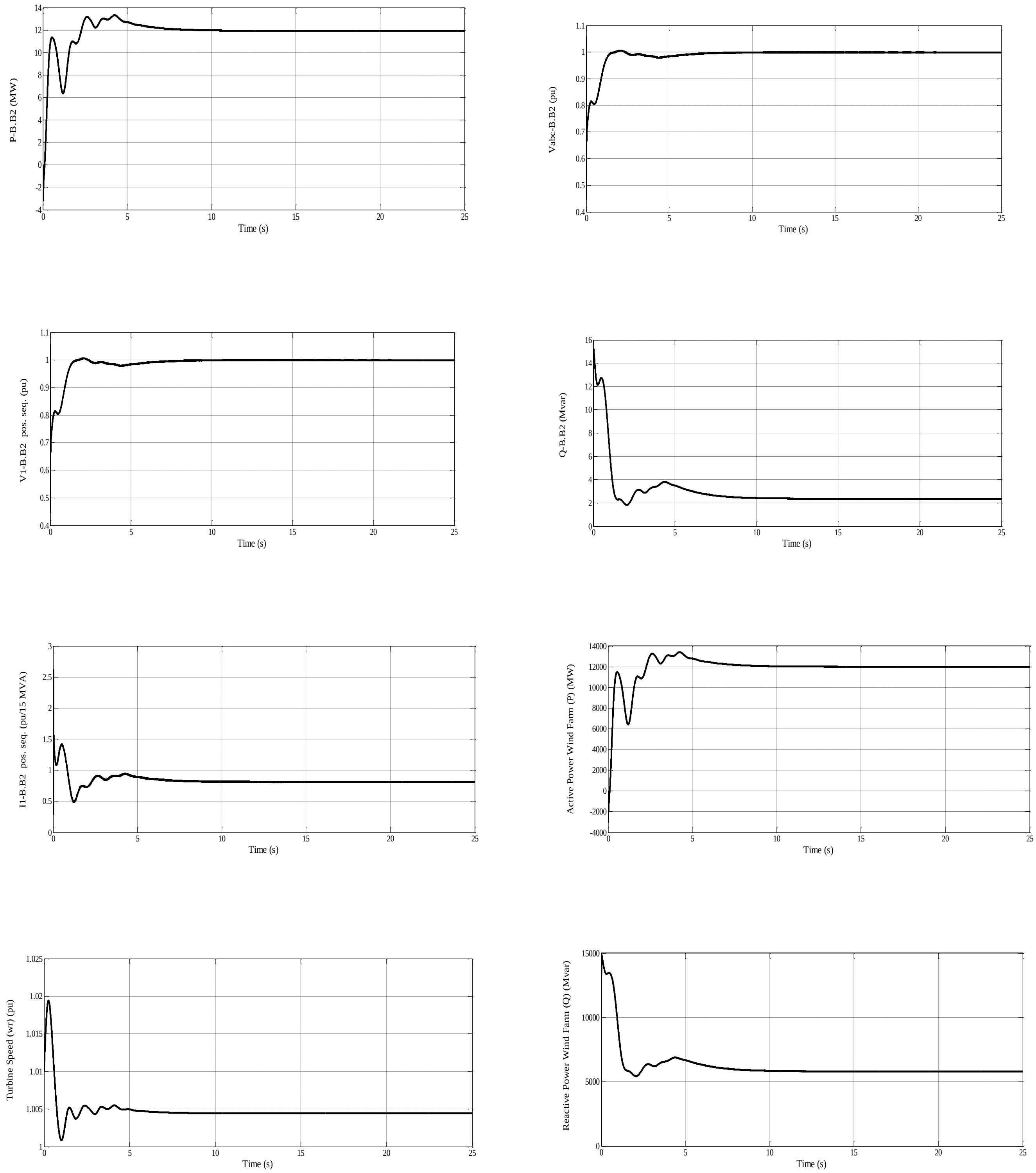

Figure (14): Results of wind power plant model with (SVC) with average wind speed (8-11) m^2/s and period time (0-1) s

B- THE DYNAMIC ANALYSIS

i. Variable Wind Speed Without Static VAR Compensator (SVC)

For the dynamic analysis to model of wind turbine that using squirrel cage induction generator (SCIG) and shunt capacitors that adjusted to include load, generators and compensation dynamic devices. The wind turbine is subjected to credible disturbances during the variable of wind speed. And nothing shows in figure (15) that the reactive power increases and the terminal voltage decreases when active power generation decreases. The increases in reactive power generation can be explained by the fact that when the active power generation decreases.

ii. Variable Wind Speed With Static VAR Compensator (SVC)

This paper used two cases to control parameters on voltage in model with (fixed Var control, voltage regulation) in transmission line and capacity. Figure (16) shows the results analysis of this simulation model with SVC var when control fixed with import voltage and active power in simulation. The reactive power supplied to the grid equals the reactive power generated by the capacitor minus the reactive power consumed by the squirrel cage induction generator. Figure (17) shows the results analysis of this simulation model with SVC var when voltage regulation that the reactive power decreases and the terminal voltage increases when active power generation increases. The decrease in reactive power generation can be explained by the fact that when the active power generation increases, the reactive power consumption of the squirrel cage induction generator increases as well. Therefore, a minor part of the reactive power generated by the capacitor will be supplied to the grid. The exact quantitative behaviour in a specific situation depends on the parameters of the generator and the grid connection.

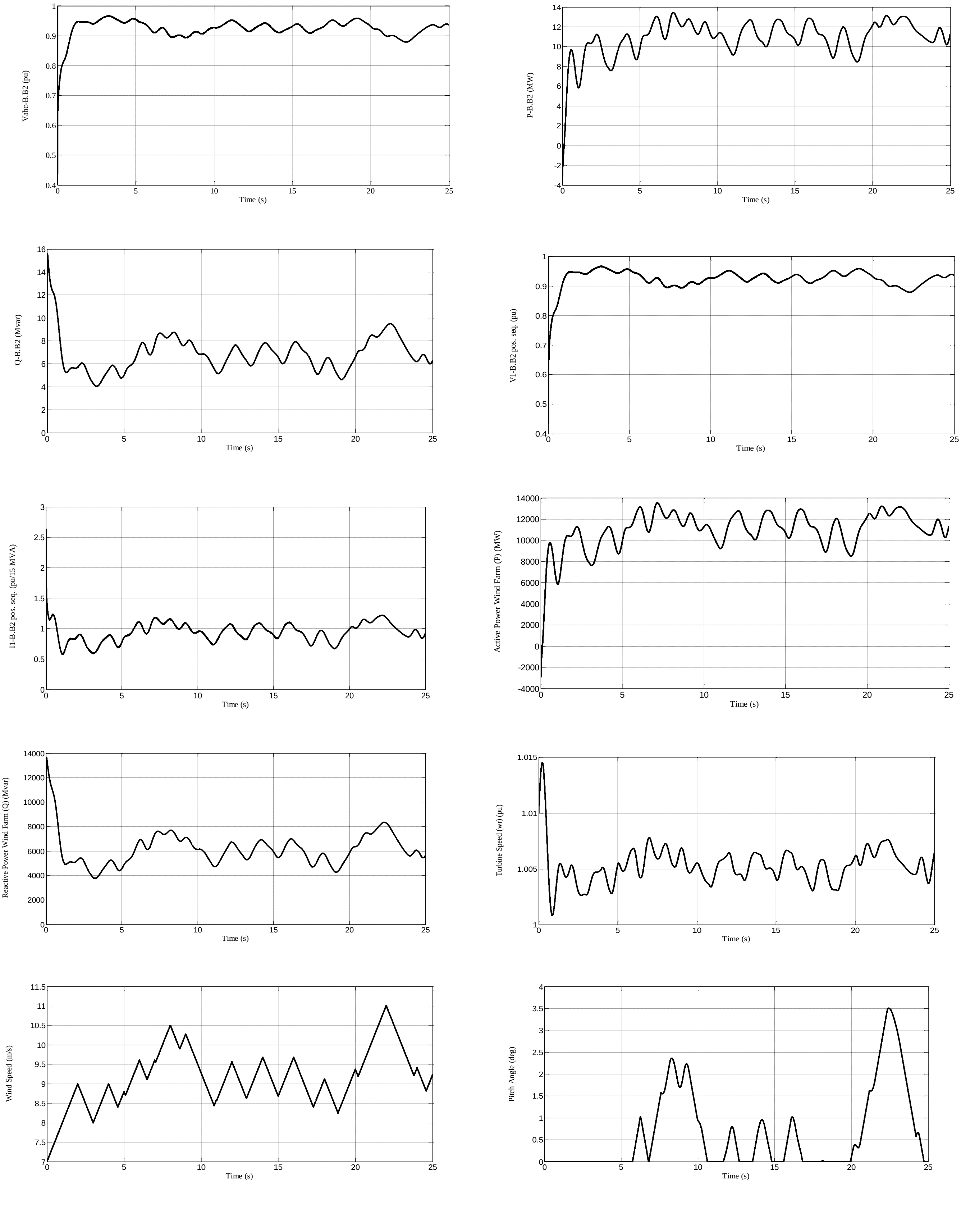

Figure (15): shows the results of wind power plant model without (SVC) with variable wind speed and average speed (4) m^2/s

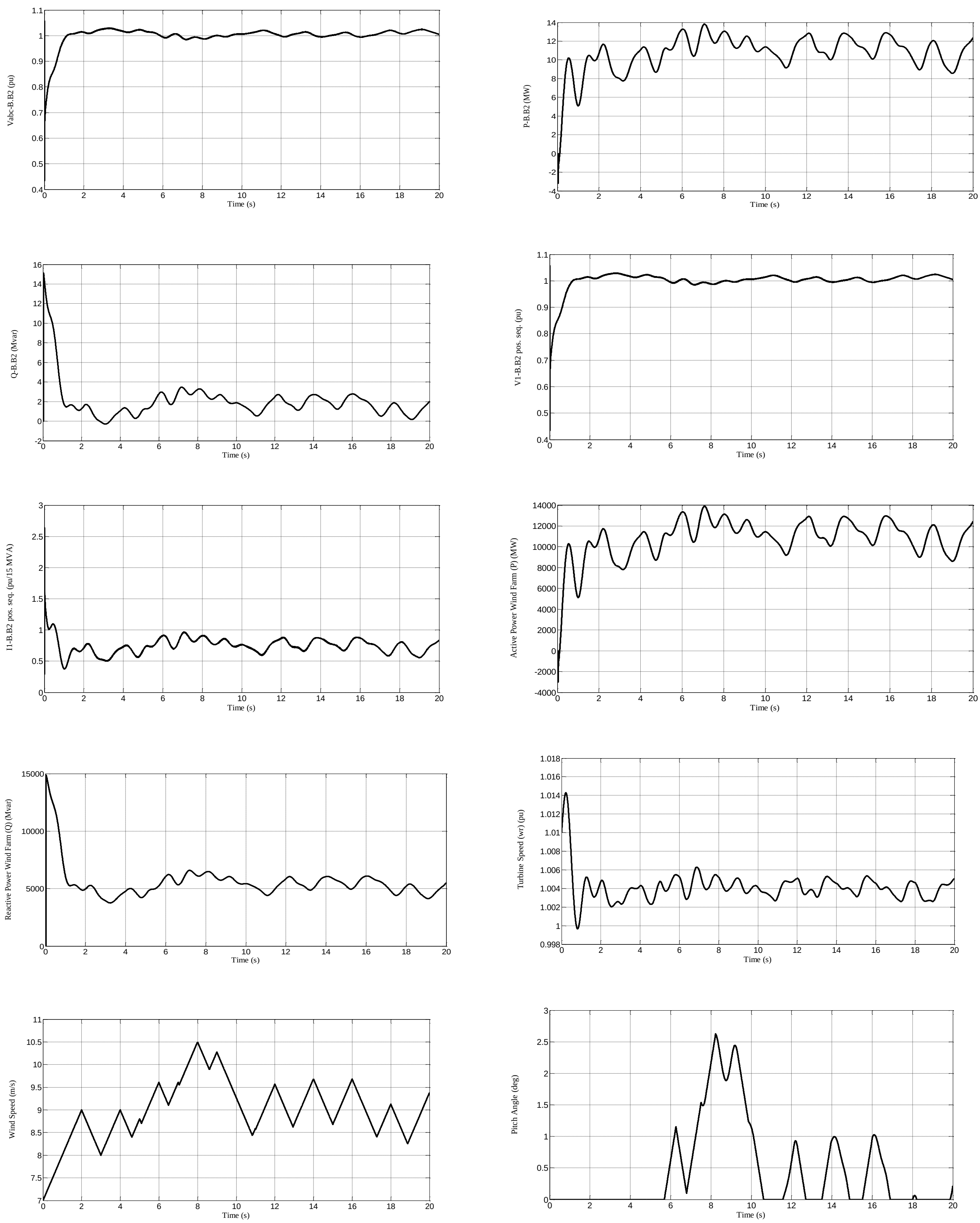

Figure (16): Shows the results of wind power plant model with (SVC) when control fixed with variable wind speed and average speed (4) m^2/s

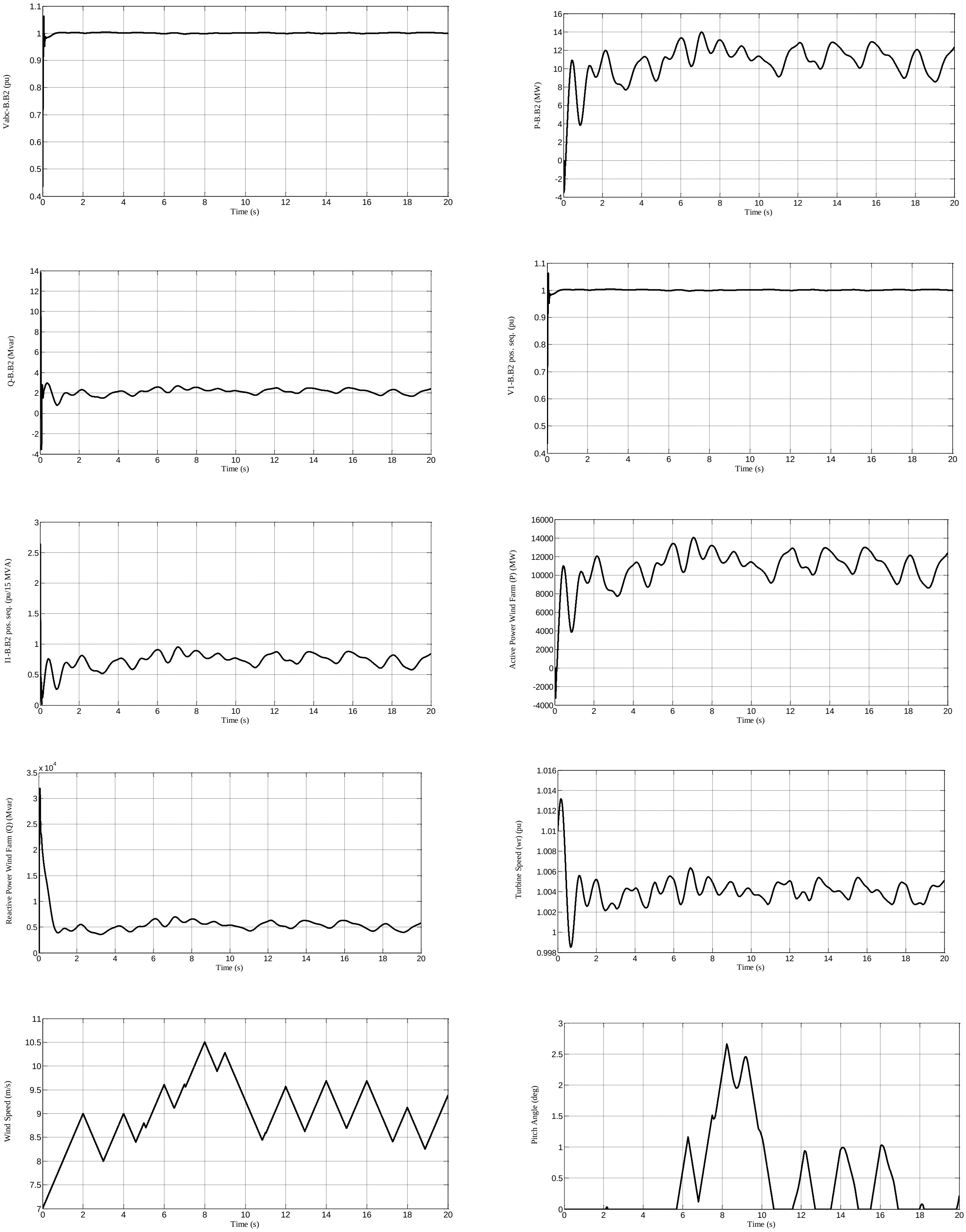

Figure (17): Shows the results of wind power plant model with (SVC) when voltage regulation with variable wind speed and average speed (4) m^2/s

13. Conclusion

In this paper the basic structure of SVC operating under typical bus voltage control and its model are described in wind turbine. The model is used to mitigate voltage instability under all conditions of steady-state and transient conditions.

The operating of (SVC) under typical bus voltage control leads to improve voltage constant to (1 p.u) and active power quality to (12 MW). The wind speed modeled with Matlab/Simulink software for two cases, fixed and variable wind speed. The simulation results of proposed model impact on the power output from wind turbines and voltage quality. Two cases of (SVC) control used in this paper SVC fixed var control and SVC var voltage regulation with variable wind speed. Observing simulation results the voltage regulation betterment to voltage control and active and reactive power stabilizes the system and working model safety.

The goal of providing voltages, reactive power support and improving the damping of system oscillations are achieved by using suitable design of SVC controller so which used in this research. This improvement can be seen in the value of Bas-Bar$_2$ ($V_{abc.B.B2}$) which changed from (0.9 p.u) to (1 p.u) and reducing the reactive power value of Bas-Bar$_2$ ($Q_{.B.B2}$) from (8 Mvar) to (2 Mvar).

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